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Moisture monitoring experience in the old town of Genoa (Italy)

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ABSTRACT

The paper describes the monitoring process, which was conducted in an important and valuable religious building in Genoa: St Matteo Abbey. It has had serious problems with rising damp both in the hall, where the damage is particularly evident on the walls of the lateral aisles, and in the space below the crypt. In 2012, the Abbot decided to use an active system of wall dehumidification, which works with electromagnetic waves. The monitoring activities were carried out simultaneously and independently by Ecodry Italia and the University, under the supervision of both Superintendence (administrative architectural heritage body) and Curia (religious administrative body). During the days agreed for monitoring, measurements were taken independently by both parties in the same points with different equipment. There were four types of moisture measurements: environmental, superficial (Electrical Resistance method), sub-superficial (Electrical Capacitance method) and deep measurements (Gravimetric method). The paper includes the results of the moisture monitoring performed from 2012 to 2016. During the monitoring process, 6 survey campaigns were carried out, which, each time, investigated the same points and parameters to obtain values comparable to each other, in order to evaluate the actual effectiveness of the installed devices. The case study revealed critical issues regarding the structure of the Abbey that should have discouraged the choice of the dehumidification equipment and that inevitably reflected negatively on the outcome of the monitoring. It is therefore not possible to deduce, from such a complex case, a univocal result that proves that the installed dehumidification system is effectively decreasing the amount of moisture present in the walls of the Abbey of St Matteo, hall, and the room under the crypt.

1. Introduction

The Abbey of St Matteo [1,2] is located within a small square in Genoa's old town. The church was built in the thirteenth century by the powerful noble Doria family. The Abbey (Fig. 1) was built in 1278 upon the remains of a previous church (1125) that had been commissioned by a member of the Doria family, but which no longer reflected the growing power of the family. In the first half of the sixteenth century Andrea Doria, a brave admiral, who was extremely influential among the European courts in the Mediterranean, commissioned new important construction work in the Abbey. He appointed Giovanni Angelo Montorsoli to renew the crypt, the chancel and the dome, although, the largest part of the work was executed in the second half of the sixteenth century. Afterwards, Giovanni Battista Castello, known as Bergamasco, and Luca Cambiaso were then appointed to radically renew the design of the Abbey [3]. They decided to significantly widen its volume by modifying the proportion of the hall, decorating it with mural paintings and stuccoes.

During the eighteenth and nineteenth century, the Abbey was enriched by the addition of noteworthy artworks and it underwent new interventions that did not modify its shape. In 1934, the Abbey was restored by Orlando Grosso, who mostly worked on its façade with its black and white striped design [4]. The Abbey has a longitudinal plan and it is constituted by a dome built on an octagonal plan, while the choir area ends in a semi-circular apse (Fig. 2). In the same area as the choir, a crypt was built in the sixteenth century and it was decorated entirely with stuccoworks by Montorsoli. In this crypt one can also observe an altar and the tomb of Andrea Doria, who himself commissioned a few years before his death in 1560. During a restoration campaign in 1962, a previously undocumented room was rediscovered under the crypt. The room was then connected to the crypt through an iron grid placed on the vault that divides the two spaces. In this room another tomb belonging to the Doria family was found alongside an urn with unidentified relics. Next to the Abbey and directly connected to it, there is a thirteen-century cloister with a quadrangular shape and covered by cross vaults resting on coupled columns.

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Fig. 1. St Matteo Abbey in Genoa's old town. The Abbey is surrounded by the houses of the old town, which is also why it is difficult to see its walls and understand the complexity of its humidity problems. In addition to a significant problem of damp rising from the ground—which the present contribution deals with—there are also issues with condensation and infiltration from above. These issues with condensation and infiltration are also linked to a small private terrace above the covering of the left aisle, which complicates the drainage of rainwater.

Fig. 2. The Renaissance style of the Abbey.

The Abbey has had serious problems with rising damp both in the hall, where the damage is particularly evident on the walls of the lateral aisles, and in the space below the crypt. Humidity in churches is an old problem, as described in numerous texts from the eighteenth and nineteenth century [5,6] and shown by a series of interventions by Montorsoli in the sixteenth century to improve the crypt's aeration (i.e. the air duct reaching the roof and grates connecting the crypt and the hall). In the 1960s, the Superintendence restored the Montorsoli's crypt, as both marble and stuccoworks were deteriorating due to high humidity levels. The restoration was led by Giacomo Raitano, who, in order to find the cause for such humidity, had some marble slabs removed. This led to the discovery of the aforementioned room located under the crypt. The rediscovered space was flooded by water flowing in from two ducts, which were obscured deep down in the room. Believing this room probably worked as a sewage system for rainwater, Raitano decided to plug the water ducts. However, water adduction filtering from the ground has never ceased (with varying intensity depending on the season). During the flooding in October 2014, this area flooded again and even two months after the event, there was still 60 cm of water.

The conservation of stuccoes, marble, mural paintings and artwork in the Abbey is currently threatened by humidity as well as the formation of saline efflorescence, which lead to widespread phenomena of disintegration, pulverisation and exfoliation (Fig. 3).

The wealth of high quality decorative work in the Abbey requires every possible intervention to prevent its gradual degradation. For this reason, in 1992 the Superintendence of Cultural Heritage led an intervention of dehumidification by injecting a chemical barrier along the longitudinal walls of the hall at around 25 cm from the floor. This intervention however, did not resolve the problem–saline efflorescence is visibly depositing around the injection holes (Fig. 4) and both marble and stuccowork are already under threat of disintegration and exfoliation.

Fig. 3. Detail of disintegration and exfoliation of marble in the low reliefs caused by saline efflorescence due to water transportation inside the marble.

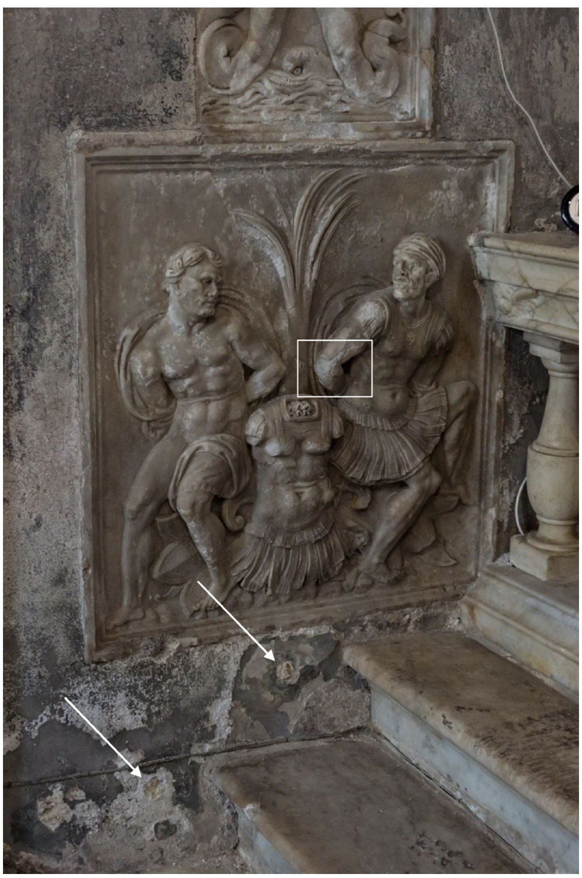

Fig. 4. Bottom in the picture, the injection holes (indicated by the arrows) of chemical barrier with saline efflorescence around. In the box the detail of Fig. 3.

2. Research aim

In 2012, the Abbot decided to try using an active system of wall dehumidification, which works with long-wave radio-electromagnetic pulses. Ecodry Italia, the company chosen for the dehumidification intervention, thanks to a leasing agreement with the Parish of St Matteo, granted the use of the equipment for three years and at the same time it monitored the dehumidification process, in collaboration with the Superintendence, the Curia, the Order of Architects and the University of Genoa.

The decision was made, in accordance with the Superintendence, to monitor the moisture levels in the hall of the Abbey and in the space below the crypt. The crypt was excluded from the measurement process because it is completely decorated with precious marble and stuccoes, on which it is not possible to run even partially destructive tests. The monitoring activities were carried out simultaneously and independently by Ecodry Italia and the University, under the supervision of both Superintendence (administrative architectural heritage body) and Curia (religious administrative body). During the days agreed for monitoring, measurements were taken independently by both parties in the same points with different equipment. There were four types moisture measurements: environmental (Electrical Resistance method), sub-superficial (Electrical Capacitance method) and deep measurements (Gravimetric method).

The paper includes the results of the moisture monitoring performed from 2012 to 2016.

Table 1
Measurements during the three years of monitoring.

Year	Monitoring date	Measurement
2012	5/12/12	0
2013	13/06/13	1
	24/01/14	2
2014	23/07/14	3
2015	12/05/15	4
2016	15/06/16	5
2018	Planned	6

3. Materials and methods

The monitoring process started in 2012 and ended in 2016. After the first values of moisture were taken in December 2012, before the installation of the devices, the survey was carried out over four years. During the first year of dehumidification (2013), two measurements were taken around every 6 months, to monitor the rate at which the moisture level was decreasing, in order to accordingly adjust the equipment in use, because if it was decreasing too rapidly, it could cause further damage to the surfaces. Afterwards, the measurements were taken once a year in May/July until 2016 (Table 1). In consideration of the difficulties encountered during monitoring, a further measurement was agreed in June 2018.

3.1. The Abbey and its subsoil

With the exception of the tiered facade built with strips of black and white stone, the walls of the Abbey and the crypt are currently not visible from any internal or external point, as they are covered with plaster, marble and/or stucco. However, archive records showed that Alfredo D'Andrade, the royal Superintendent of Piedmont and Liguria's monuments at the beginning of the twentieth century, during a period of work he conducted in 1911 on both the cloister and the church, was unsuccessful in finding any trace of the Abbey's medieval walls [4]. It is then plausible to believe that the walls, which date back to the middle of the sixteenth century, were made—as it was common at the time—of split stone (marl limestone), full fired-clay bricks, and lime mortar. Core sampling, taken to measure humidity deep within the walls, showed different materials within a short space: marl limestone, fired-clay bricks with different firing degrees, air lime mortar and sand from the shoreline at Sampierdarena (a neighbourhood of Genoa). Unlike the hall, the walls of the room under the crypt were built entirely with fired-clay full bricks, homogeneous in composition and firing degree. Similarly, in this case, the hypothesis regarding the walls were carried out based on the materials extracted in the core samples, which were taken to measure humidity deep within the walls.

The Abbey, built on clay-marlstone soil at the edge of a natural slope, which is now urbanised, is located in an area favouring the collection of rainwater that filters down from the soil and

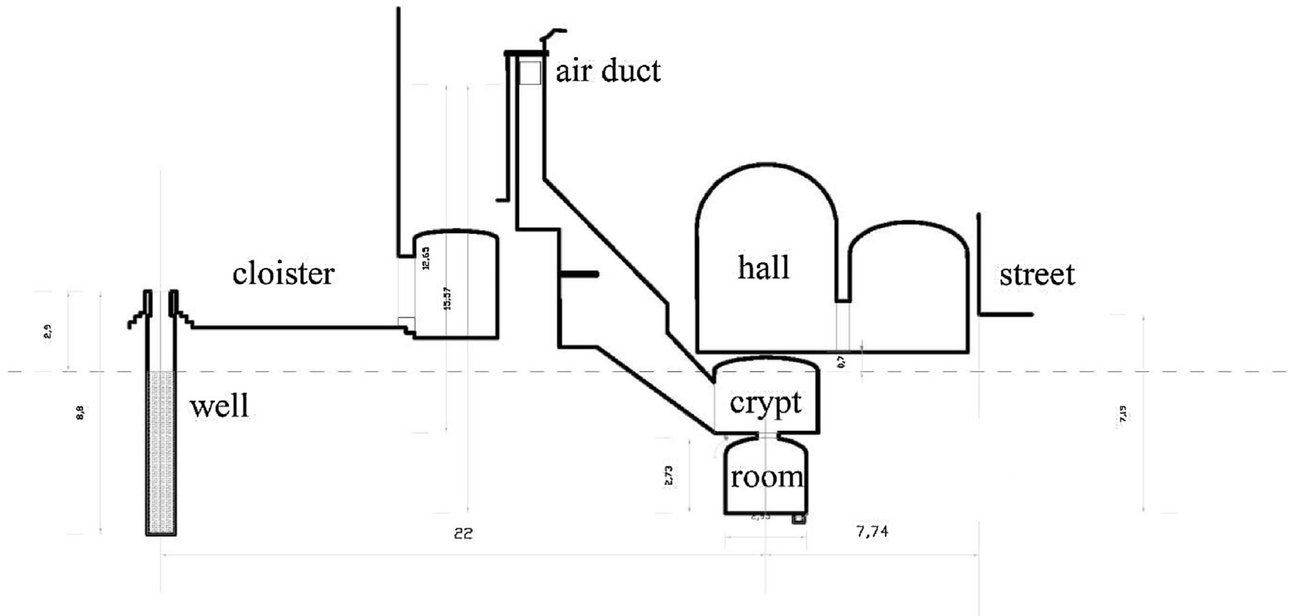

Fig. 5. Partial section of the Abbey (hall) with crypt and its air duct, underneath room, lateral cloister, and well (edited from R. Lavezzaro).

gathers in an underground aquifer. In the adjacent cloister, there is a well intercepting water at 1.5 metres from ground level, i.e. in correspondence with the Abbey's foundations (Fig. 5).

The presence of this well is a clear sign of underground water, as demonstrated additionally by the various damp problems affecting basements and ground floors in the adjacent buildings. In 2014, one of the buildings belonging to the Doria family, directly attached to the church's apse, underwent a diagnostic campaign to understand the causes of dampness formation in its basement. Geognostic surveys carried out in the basements close to the Abbey, showed the presence of an Ortovero clay substratum, which during the Early Pliocene had deposited on the limestone substratum of Mount Antola in Liguria. Clay, alternated with layers of sand, does not allow water to filter through or aquifer levels to form, and being impermeable to water, it often causes superficial water flow. In the Abbey's case, the overland flow may be occurring exactly around the church's foundations, as demonstrated by the fact that the main sections of degradation are within the first two metres of the church's walls, as well as in the crypt and the room underneath, which are both completely interred. The cause of the humidity is a consequence of the geo-morphological context of the Abbey and its surrounding area, hence it is necessary to adopt all viable solutions to gradually reduce the dampness levels and the degradation of the materials of this important historical artistic building.

3.2. The wall dehumidification system

In 2012 Ecodry Italia installed 5 Zeta III devices in the Abbey of St Matteo, including 4 in the church and 1 in the room under the crypt (Fig. 6). As reported in the informative material provided by Ecodry Italia, the Ecodry devices emit long-wave radio-electromagnetic pulses, which, associated with a bimodal magnetic field (< 40nT at a distance of 0.5 m), intervene in the ascensional and transversal processes of the water molecules within the entire wall structure. With electromagnetic impulses, Ecodry systems disturb the balance of electro-physical energies, which underlie all the natural movements that water is able to carry out between the ground and the foundations and within the structure boundary. This induced imbalance cancels the forces of an electrochemical and osmotic nature that guide the movements of the water molecules inside the artefact. As a consequence, the water drains into the ground, carrying with it also the dissolved salts in ionic form. Ecodry systems are not very invasive because of their small dimensions ($33 \times 20 \times 4$ cm)—they only need to be fixed to the wall with plugs and connected to the electrical network.

3.3. Electrical Resistance method

This is a non-destructive method that measures the electrical resistance of a material, which diminishes in relation to the increase of the water quantity [7–10]. The devices feature metal electrodes that are connected to a high-frequency voltage generator and a measuring circuit. When measuring the moisture content of an object, the electrodes are pressed against the object. The capacitance between the electrodes is then proportional to the moisture content of the material. The results are measured in arbitrary units, but the method has been used in order to detect relative differences over time.

The advantages of resistive sensors is their cheap price and small size. The disadvantages of resistive sensors are their accuracy, sensitivity and dependence on temperature.

3.3.1. Electrical Resistance method for measurements on the surface

The values were recorded based on a 30×30 grid along all the walls of the hall (around 15 metres) and the space below the crypt (around 3×4 metres), starting from the ground and arriving at around 2 metres high [7–10]. An example of incoming data on superficial moisture is summed up in Table 2, which compares the data taken in the same moment and from the same spot, but with different equipment (1-Gann BL compact B; 2-Protimeter mini; 3-Protimeter Surveymaster), each having its own scale. Particular attention was placed on signalling the presence of saline efflorescence (calcium and magnesium sulphates), because they cause overestimation of the moisture content [11]. During each monitoring day, for superficial moisture only, 72 charts, as in the example below, were compiled with almost 1300 data. The total amount of data collected during these three years, for superficial moisture only, was around 8000 units.

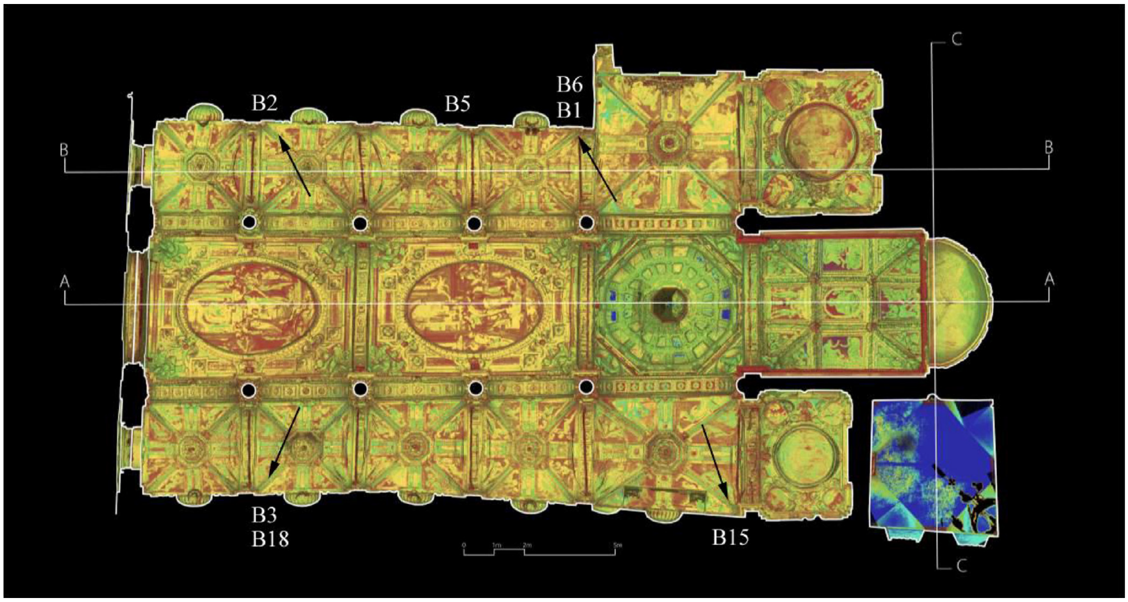

Fig. 6. Plan of San Matteo Abbey with hypographic view of the vaults and positioning (black arrows) of the Ecodry Italia devices. Survey carried out by C. Battini, R. Babbetto and R. Lavezzaro (edited from R. Lavezzaro).

Table 2
Example of superficial moisture measurements. For each measuring instrument (1-2-3), the measurement range is shown in the its own scale (1-Gann BL compact B = 0.4–6%; 2-Protimeter mini = 6–90%; 3-Protimeter Surveymaster in Wood Moisture Equivalent [WME] mode = 6–99.9%).

Distance from the counter-façade	Height from the ground	Superficial temperature	Superficial moisture 1	Superficial moisture 2	Superficial moisture 3
	cm	°C	0.4–6	6–90	6–99.9
G (cm 210)	180	18.6	5.1	46	39.6
	150	18.6	5.1	46	66.3
	120	18.6	5.1	62	99.9
	90	18.6	5.1	37	34.7
	60	18.6	5.0	55	63.9
	30	18.6	5.0	23	31.4

The surface measurement gives an estimate of the structure moisture, but not the real moisture of the structure. The surface moisture is easy to measure with an electric moisture meter but the measurement method produces high levels of background noise. Indeed, the measurement results from different surface-moisture meters differ from each other. The meters report different values. The dispersion with the different surface-moisture meters is large.

3.3.2. Electrical Resistance method for in depth measurements

Together with the 5 Zeta III devices, Ecodry Italia installed, in the same points, a number of sensor probes inside the wall at 20 cm depth and at a height of 40 cm from the floor (in the Church) and at 110 cm from the floor (in the room under the crypt). The probes have been inserted into holes made in order to measure the humidity in depth. The difference in height was due to the possibility of drilling the wall, depending on the presence of decorated plaster and marble covering. The probes, connected to the Zeta III devices, daily measured the electrical resistance values that were recorded inside the device by means of a data-logger. Periodically, Ecodry technicians downloaded the data recorded by the various devices, then processing some graphs with monthly averages. In this case, the monitoring was conducted only by Ecodry Italia that kindly made available, at the end of the three years, the data obtained.

3.4. Electrical Capacitance method

This is a non-destructive method that measures the dielectric constant of a given material, which sensibly increases even with small quantities of water (Protimeter Surveymaster) [7–10]. Although the European standard EN 16682 [11] stresses the importance of combining the method of electrical capacitance with the analysis of the electrolytes within the walls, the present research only documents the presence of visible saline efflorescence (calcium and magnesium sulphates), which could alter the data. The moisture measurements were carried out between 2 and 4 cm from the surface. An example of incoming data on superficial moisture is summed up in Table 3. During each monitoring day, for sub-superficial moisture only, 72 charts, as in the example below, were compiled with more than 400 data. The total amount of data collected during these three years, for sub-superficial moisture only, was around 2500 units.

Table 3
Example of sub-superficial moisture measurements. For sub-superficial measuring instrument, the measurement range is shown in the its own scale (Protimeter Surveymaster in Search–REL mode = 60–999).

Distance from the counter-façade	Height from the ground	Superficial temperature	Sub-superficial moisture
	cm	°C	60–999
G (cm 210)	180	18.6	796
	150	18.6	925
	120	18.6	903
	90	18.6	967
	60	18.6	843
	30	18.6	209

Table 4
Example of in depth humidity measurements. ATRO represents the relationship between initial weight (PI) and residual weight (PR).

Measurement points	Depth from the surface	Initial weight (PI)	Moisture	Dry mass	ATRO (PI/PR)	Residual weight (PR)
	cm	g	%	%	%	g
B7	4	9.07	19.73	80.26	124.58	7.28
B8	15	7.79	20.79	79.21	126.25	6.17

3.5. Gravimetric method

This destructive method measures the quantity of water in a material sample, which is weighed immediately after having been taken and after having dried with a thermoscale (Kern DLB [7–10]). The gravimetric method is considered as primary reference, according to EN 16682 [11].

The amount of incoming data for the measurements of in-depth humidity was less than that of the data analysed in the previous paragraph, because these measurements required drilling into plaster and wall to reach a depth of around 15 cm. The survey points were chosen in accordance with the Superintendence and based on their relevance, but also on the effective possibility to drill a hole in the walls to take a sample of the humid material. The measurements were taken in 12 points (8 in the hall and 4 in the room under the crypt) at two levels of depth: 4–5 cm and 14–15 cm from the surface. The choice was based on the attempt to monitor the moisture between the plaster and the wall, arguably 4–5 cm deep, as well as inside the wall. The test was carried out by drilling into the plaster and wall in the chosen points with a low-speed rotation drill, in order to minimise the overheating of materials, and by weighing the powdered humid material (up to 160 g) extracted from the hole. The weight was then compared after the sample had been dried in a moisture analyser.

The Table 4 is an example of the incoming data regarding humidity in depth and it also shows the data obtained by the equipment used.

Regarding moisture deep within the wall, during each monitoring day, 12 charts were compiled with 120 data, which in three years counted more than 700 data points to manage.

4. Results

During the monitoring process 6 survey campaigns were carried out, which, each time, investigated the same points and parameters to obtain values compatible between each other, in order to evaluate the actual effectiveness of the installed devices. Data comparison had to be carried out not only between measurements taken in different years, but also between measurements carried out during the same year but with different moisture surveying techniques. Moreover, it was important to compare the measurement data taken by the University with those carried out in the same day by Ecodry Italia. For this reason, there was a relevant amount of data to be acquired, archived, interpreted, and transmitted. In the first case, because this four-year monitoring process inevitably involved a high number of people, it was necessary to have a precise process to acquire, control, and archive data, to minimise errors that could result from different people working one after the other. In the second case, to have a clearer picture of the overall situation—there was not an evident trend of effective dehumidification—it was pivotal to develop efficient methods to visualise data and have an immediate comparison between years and measurements. On the other hand, regarding the values of superficial and sub-superficial humidity, which are not invasive, a higher number of data was gathered to effectively represent the variation in moisture on the surfaces. The measurements of in-depth humidity and especially the many superficial measurements could have also been gathered and then transferred onto charts, but because of the great quantity of data collected, it would have been extremely difficult to compare it and obtain a complete picture of the situation. Hence, the need for a tool, that was easy to use and was able to gather and visualise a great deal of information on site. Consequently, the tree-dimensional survey and the algorithm created expressly for the present case, accelerated the work process and showed the phenomena observed in a clear form [12–14].

The results of the analyses carried out by the University of Genoa and Ecodry Italia are comparable, and the small differences are within the range of systematic errors as well as the variability of the samples analysed. Ponderal analyses provided more reliability. However, the results are not entirely coherent in the hall (Figs. 7 and 8) nor in the room under the crypt (Fig. 9).

The fluctuating humidity values recorded do not demonstrate a decreasing trend. On the contrary, the values are actually increasing. The survey values in the room under the crypt were marginally more stable—the walls in the room are made of full fired-clay brick bonded together with lime mortar, and exposed to the rising and capillary infiltration in a more uniform way on all sides. However, in this case also, the interpretation does not show a clear decreasing trend. Compared to the hall, the (damp) more constant microclimate of the room under crypt, which is also due to the absence of external openings and to the fact that the room is under the level of the ground, is reflected in the humidity samples, which do not show any significant variation at 4–5 cm and 14–15 cm from the plastered surface (Fig. 10).

5. Discussion

Environmental humidity measurements were only taken during the monitoring days, because it was not possible to maintain a constant control. This is one of the limitations of the work, because it would have been useful in these four years to have had environmental data—outside the church (in the opposite square and in the adjacent cloister) and inside the church (in the hall, the crypt, and in the space underneath the crypt)—in order to better understand the condensation phenomena which seemed to be particularly pronounced in the church of St Matteo. The environmental data and the data connected to the moisture levels measured deep within the walls were organised in charts, and visualised in diagrams.

The only continuous monitoring, performed in this case, is the one made by Ecodry Italia with the probes-inserted in the walls of the hall and the crypt (see Section 3.3.2). The outcome of this monitoring allows us to conclude that, despite the diversity of electrical resistance values recorded from point to point, there is an annual periodicity of the data that corresponds to a recurring phenomenon. In fact, there is an annual increase in electrical resistance in February/March and a decrease in electrical resistance in the months of July/August. Since the electrical resistance decreases with the increase in the amount of water contained in the masonry and that the wettest months (Table 5) are not always the same but annually vary between those of October, November, December, January, February, and March, we must imagine that such a constant periodicity is linked to a different phenomenon. For example, the surface condensation humidity inside the holes in the wall where

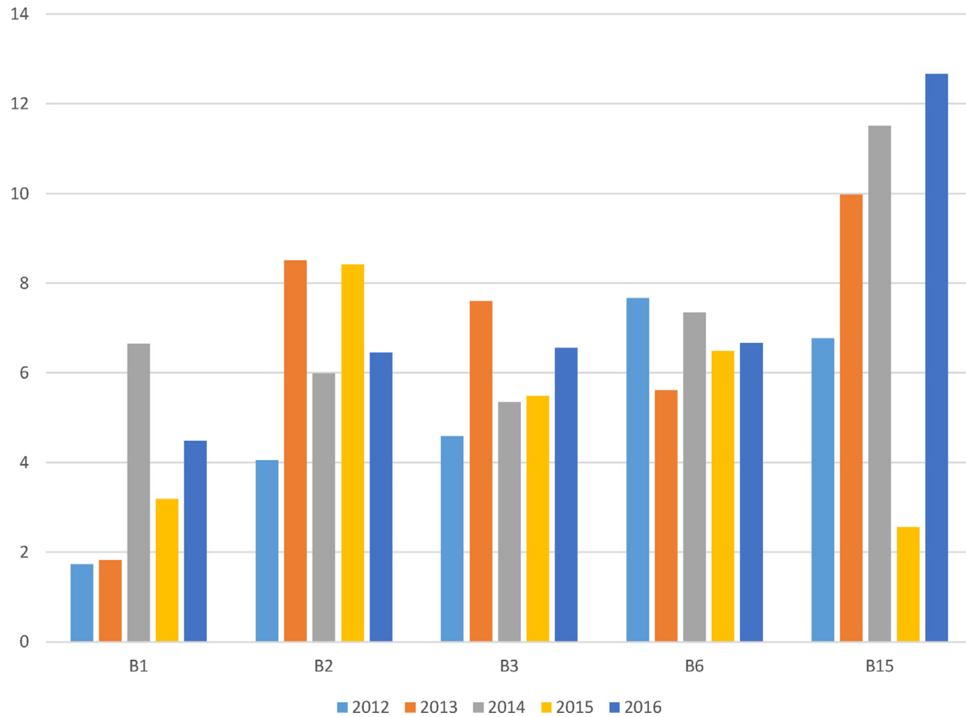

Fig. 7. Humidity measurements [%] carried out with the gravimetric method in a series of points in the hall (B1, B2, B6 in correspondence with the left aisle and B3, B15 in correspondence with the right aisle) at a depth of 4–5 cm from the surface and at a height of around 40 cm from the floor (measurements taken by the University of Genoa).

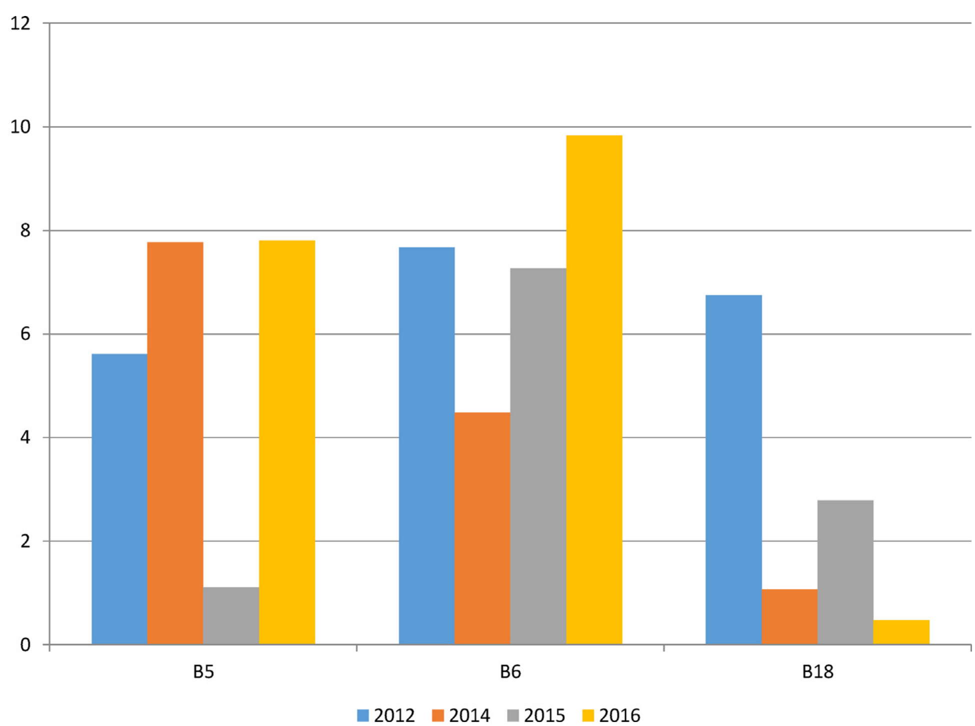

Fig. 8. Humidity measurements [%] carried out with the gravimetric method in a series of points in the hall (B5, B6 in correspondence of the left aisle and B18 in correspondence of the right aisle) at a depth of 14–15 cm from the surface and at a height of around 40 cm from the floor (measurements taken by the University of Genoa).

the probes are housed, maximum during the summer months and minimal during the winter months. The latest data, downloaded by the technicians of Ecodry Italia on 1/08/2017 (after the end of the monitoring) seems to indicate a slight improvement in 2 points out of 4 of the hall and in the room below the crypt, however the data is not clear enough to confirm an improvement in conditions, given the particularly hot and dry climate of the year.

The problem of moisture condensation is very evident in the church of St Matteo, so much that it appears overwhelmingly in the summer months on the numerous marble surfaces that cover and decorate the interior of the church and the crypt (Fig. 11).

Obviously, the monitoring of surface moisture has suffered greatly from the condensation during the spring-summer months, so as to provide periodically higher relative readings in the months

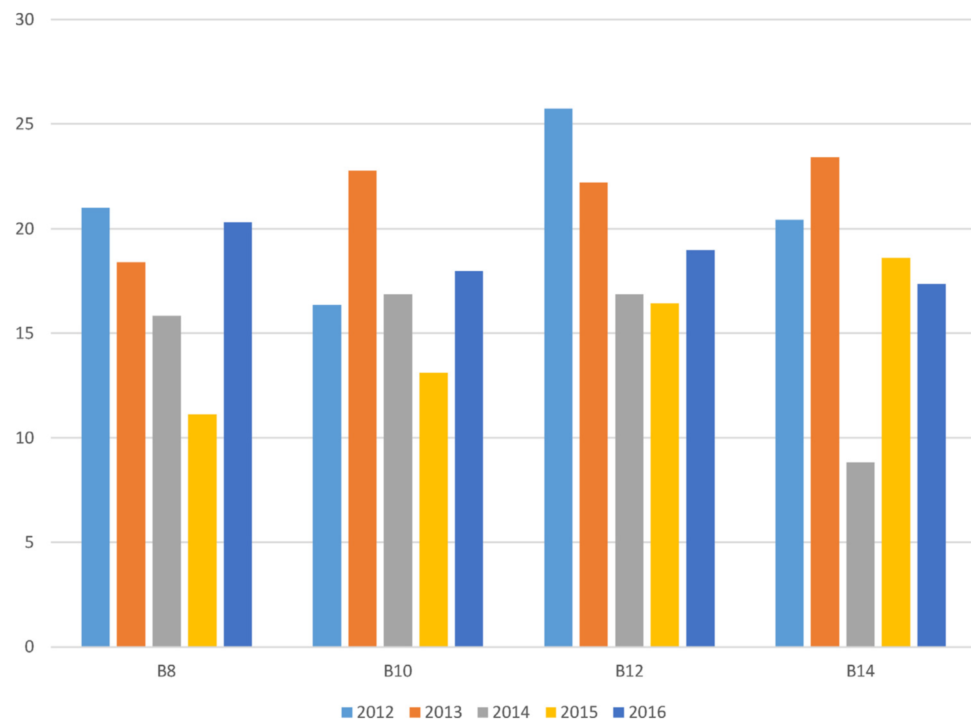

Fig. 9. Humidity measurements [%] carried out with the gravimetric method in 4 points in the room under the crypt (B8, B10, B12 and B14—a point for each of the four walls of the room) at a depth of 14–15 cm from the ground and at a height of around 110 cm from the floor (measurements taken by the University of Genoa).

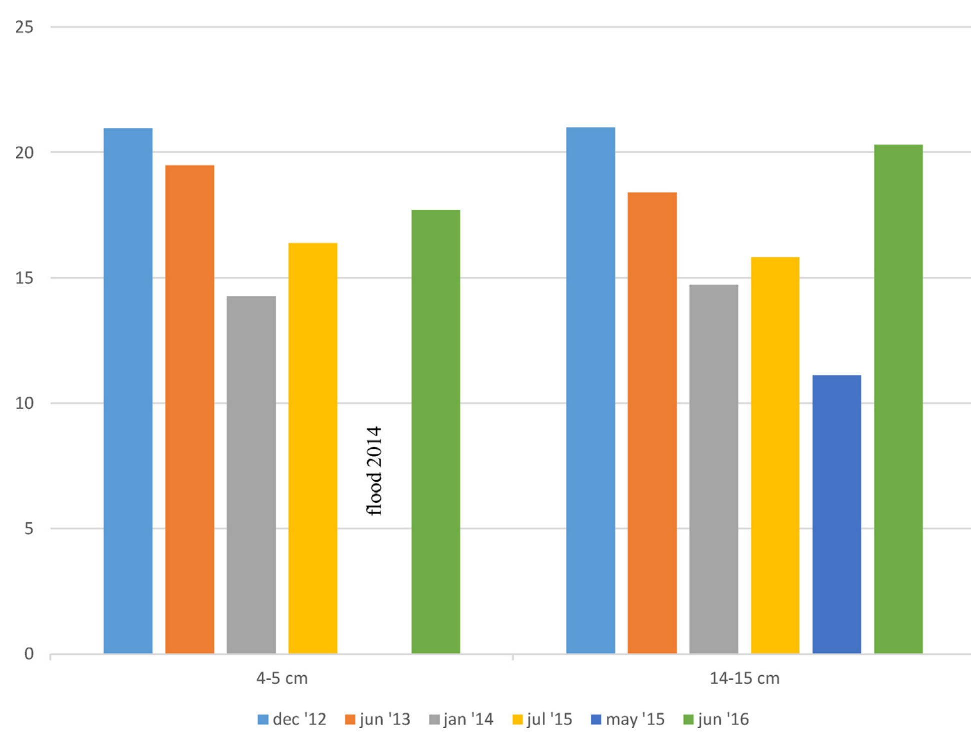

Fig. 10. Graphs indicating the moisture flow [%] measured deep in the walls of the room under the crypt, point B8 (measurements taken by the University of Genoa). In May 2015 the measurement of superficial humidity was not taken because the plastering was visibly steeped in water after the flooding of October and November 2014.

of June-July compared to the months of January and February. The average relative air humidity (Table 6) shows monthly humidity levels nearly always higher than 60% and often higher than 70%. Table 7 shows the humidity variation in June and July 2017. It is evident that the dew points, nearly always higher than 18 °C, cause widespread condensation on the Abbey's plastering and marble, where the temperatures are always lower.

This situation did not allow reading a decrease in surface humidity over the three years.

Perhaps the most reliable data, although affected by a series of problems that will be described below, seems to be that of monitoring the humidity in depth in the masonry. In this case, the problems of reading the data are related to the church walls, which are particularly heterogeneous especially in the hall, and not visible from

Table 5
Pluviometric data of cumulative precipitation (measured in mm) recorded in the city of Genoa from 2012 to 2017 (ARPAL—Regional Agency for the protection of the Ligurian Environment—Genoa station functional centre located in Viale Brigate Partigiane). The quantities of greater precipitation (greater than 200 mm per month) are recorded in bold, which are recorded in different months over the years, between October and March. The two months in which anomalous events (flood with cumulative precipitations greater than 400 mm per month) that should have obviously changed the detection of the probes are indicated in grey.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2012	34.4	11.6	57.2	115.0	64.6	15.0	10.4	78.2	70.8	147.2	**251.4**	41.6	897.6
2013	122.0	15.4	**228.0**	91.8	142.4	26.4	51.2	55.6	122.8	86.2	133.2	**229.4**	1304.4
2014	**254.8**	**254.8**	78.0	54.6	46.8	14.8	23.6	56.6	31.6	**432.2**	**518.8**	130.6	1897.2
2015	47.6	85.8	32.8	48.4	29.8	30.8	1.2	113.6	106.6	4.6	39.0	15.8	556.0
2016	15.8	**200.2**	67.0	6.4	78.6	45.2	18.8	21.4	82.0	65.8	122.2	17.4	740.8
2017	7.2	52.2	29.6	13.2	55.2	2.2	58.8	2.2	53.8	3.6	80.8	149.2	508.0

Fig. 11. Moisture condensation on the marble altar of the crypt (15/06/2016): *RH* 96%, *T* 19 °C, *DP* 18 °C.

Table 6
Average Relative air Humidity (*RH* in %) data recorded in the city of Genoa from 2012 to 2017 (ARPAL—Regional Agency for the protection of the Ligurian Environment—Genoa station functional centre located in Viale Brigate Partigiane). In bold the percentage of higher *RH* (above 70%) that are recorded in different months between December and February but also July and August. The month in which the flood occurred is shown in grey. Because the data from September 2015 is missing (which was likely not collected by the ARPAL agency, due a malfunction), the decision was made to use the data collected in September 2015 in the weather station of Genoa Quezzi.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	RH	RH	RH	RH	RH	RH	RH	RH	RH	RH	RH	RH
2012	62	55	62	71	71	73	71	68	69	74	67	51
2013	63	49	64	67	65	64	59	56	65	70	59	70
2014	**77**	**79**	66	74	67	69	72	**78**	70	73	**80**	69
2015	61	60	61	70	74	68	69	66	62	71	69	**78**
2016	65	72	61	67	65	73	68	61	63	67	70	64
2017	47	72	62	64	66	71	**75**	67	63	63	60	57
Average	62.5	64.5	62.6	68.8	68	69.6	69	66	66	69.6	67.5	64.8

the interior because they are completely covered with plaster. As well as externally, the Abbey is partly interred, partly surrounded by buildings, which were grafted to it over time, and in the remaining parts it is covered with plaster. The impossibility of seeing the wall texture and its heterogeneity has resulted in the difficulty of sampling homogenous material within the masonry. Therefore, the holes made with the drill at low speed in some cases have intercepted the stone (marl limestone), in other cases the brick (different types of brick as seen from the composition of the mixture and from the firing), in others still the bedding mortar.

The diversity of material, and therefore of moisture absorption, has led to a difficulty in reading the data which, on the whole, have been found to be inconsistent.

The masonry of the room under the crypt is more homogeneous, being built with full bricks with lime mortar as bedding. In this case, the data concerning the depth humidity values, after initially decreasing, even though it fluctuated until 2014/15, increased again in 2016 (Fig. 12).

6. Conclusions

The Abbey of St Matteo has been chosen by Ecodry Italia for the testing of its dehumidification tools by virtue of the continuous and historical presence of humidity but also of the centrality and representativeness of the building. The abbey is in fact one of the most precious religious buildings of the old city, both from the architectural point of view and from the historical-artistic point of view. It is located next to the headquarters of the Order of Architects, which is housed in the nearby rooms of the cloister of St Matteo, and a

Table 7
Average Relative air Humidity (*RH*) and air Temperature (*T*) data recorded in the city of Genoa in June and July 2017 (ARPAL—Regional Agency for the protection of the Ligurian Environment—Genoa station functional centre located in Viale Brigate Partigiane). The dew point (*DP*) was calculated for each day of the month. In bold the percentage of higher *RH* (above 70%).

Day	June			July		
	RH	T	DP	RH	T	DP
	%	°C	°C	%	°C	°C
1	70	22.1	16	70	22	16
2	**73**	22	17	**73**	22.1	17
3	**74**	22.2	17	**75**	23.7	19
4	**79**	23	19	69	24.2	18
5	**73**	22.6	18	67	24.5	17
6	**74**	22.5	17	65	24.8	18
7	68	21.7	16	66	25.4	18
8	55	22.8	13	60	26.2	17
9	55	23.8	14	69	26.6	21
10	60	23.1	15	**94**	25.3	24
11	60	25.1	17	**95**	24.8	24
12	69	25.4	19	**96**	24.8	24
13	**72**	24.8	19	**88**	26.3	24
14	**81**	24.1	20	**81**	27.4	23
15	**83**	25.1	22	43	28.5	14
16	**84**	25.8	23	56	25.8	16
17	62	28.2	18	55	25	15
18	53	26.7	16	53	26.2	16
19	49	25.4	14	**77**	25.1	20
20	55	25.4	15	**79**	24.8	21
21	68	24.7	18	**72**	25.8	20
22	**76**	25.3	20	**95**	25.5	24
23	**83**	25.4	22	**98**	25.8	25
24	**88**	25.2	23	**90**	25.9	24
25	**96**	25.1	24	54	25.8	16
26	**77**	25.8	21	58	24.7	16
27	**73**	26.8	22	**72**	24.5	18
28	**86**	25.3	22	**89**	25.2	23
29	70	23.2	17	**83**	26	23
30	67	22.3	15	**86**	26	23
31				64	27.9	20

short distance from the Curia, the Department of Architecture and Design, the City and the Superintendent that all the entities that Ecodry Italia has contacted for being educated and involved in the promotion action.

However, the case study presented important issues that should have discouraged the choice and that inevitably reflected negatively on the outcome of the monitoring. First of all, the incomplete knowledge of the actual cause of rising damp and, above all, the impossibility of deepening this aspect without making tests in the ground and inspecting the present underground canals. Secondly, the great wealth of the abbey, which translates into valuable surfaces on all the walls that not only prevent the view of the wall but also prevented it from working a little more freely with samples and tests. Finally, the presence of a previous dehumidification intervention (chemical barrier), whose existence was discovered only during construction, may have altered the capillary absorption capacity of the masonry. The phenomenon was already difficult to understand due to the presence of a heterogeneous masonry consisting of stones (not very porous), bricks and mortar (very porous) that have a different capillary absorption and therefore determine discontinuity of reading depending on the reference points.

Ultimately, the concomitance of 3 years of monitoring with the paroxysmal event of the floods in 2014 (October and November) allowed on one hand to evaluate the behaviour of the building under conditions of particular stress, but on the other altered some readings, at least with regards to the room under the crypt after the flood (Fig. 12).

It is therefore not possible to deduce from such a complex case a univocal result that proves that the installed dehumidification system is effectively decreasing the amount of moisture present in the walls of the Abbey of St Matteo, hall and local under the crypt.

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Fig. 12. The room under the crypt completely flooded with 60 cm of water (Ecodry Italia 5/12/2014).

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